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Boston Society of Natural History.

GUIDES FOR SCIENCE-TEACHING.

No. II.

CONCERNING A FEW COMMON PLANTS.

By GEORGE L. GOODALE.

SECOND EDITION.

BOSTON:
D. C. HEATH & COMPANY.
1886.

THIS Series of Guides for Science Teaching is published as supplementary to courses of Lectures on Botany, Zoölogy, and Mineralogy now being given by the Teachers' School of Science of the Boston Society of Natural History. The average attendance this year is about five hundred, and all persons are furnished with specimens in order that they may be taught how to observe and how to teach others to observe. Professor Goodale has demonstrated that even so large audiences as these can be successfully instructed by this method.

The Teachers' School of Science was inaugurated and supported for some years through the generosity of Mr. John Cummings. The present enlargement of its field of usefulness is now, however, due to the personal labors and munificence of several ladies of Boston, already well known for their public benefactions.

ALPHEUS HYATT,
Custodian.

FEBRUARY, 1879.

Boston Society of Natural History.

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INTRODUCTION.

THE botanical lessons in the Teachers' Course in Science, for 1878–79, are given at that period of the year which is most unfavorable for the selection of illustrative material. During the preparation of the lessons under this serious disadvantage, and while the choice of objects for study was still under advisement, it became clear that a few printed details respecting the illustrations and their use would be of service to the teachers in attendance upon the course.

At the same time, a fear was felt that such a printed supplement might perhaps restrict the application of the methods of study recommended, by binding some teachers to the use of only the scanty materials here employed. It is, therefore, with some misgivings that the supplement has been prepared. The design of the lessons is to point out one method by which a few of the more important and easily observed facts can be taught, respecting the structure, growth, and work of plants; while the purpose of this guide is to call attention to the manner of preparing the objects selected for such elementary study, and to furnish some suggestions as to the way they can most readily be turned to good account. It must not be forgotten that in autumn, spring, and summer, more abundant material for study is at hand, and the range of choice is at those seasons very wide. Therefore, the present outline must be looked upon as one which a judicious teacher can change for the better: every object for study may be replaced by others; and the sequence in which the objects are examined may be modified, *provided* the pupils are induced to observe for themselves, to compare for themselves, and, in short, to do their own thinking. The teaching which is advised in this course of botanical lessons is based upon the belief that the pupil must earn his facts; that, in general, facts which a pupil may acquire for himself are to be placed within his reach, but not in his hands. He must make some exertion to get knowledge, in order that it may become his. But in what way can a pupil be led to exert himself? Certainly not by having every thing done for him.

In applying this general statement to the case in hand, it may be said, first, that the interest which children take in the more attractive plants around them, in the brilliancy and varied shapes of flowers, and in the growth of seedlings, should be increased by every means at the teacher's command.

It may be remarked, secondly, that the information which the teacher imparts respecting plants in which the child is interested should be furnished with the ultimate design of leading the pupil to observe for himself; and, with tact, this can be done even with the youngest. Answer all questions which the pupil cannot answer for himself by careful examination of the plant before him, but do not show him what he ought to see with his own eyes, and without help.

The successful attempts made by the late Professor J. S. Henslow, of Cambridge, England, to introduce botanical study into the parish and common schools, are doubtless known to many readers of this guide; but it may not be so widely known how far that model teacher insisted upon self-help.

In his "Practical Lessons on Botany," * Professor Henslow makes use of the following language: —

"In order to employ Botany as a strictly *educational* weapon, we must not confine ourselves to telling children the names of plants, how they may be artificially grouped, what properties they possess, or the few physiological facts hitherto established with more or less precision respecting them. We may give any one valuable instruction of this description, either orally or by books, without having exacted the requisite attention to the *structure* of plants which demands a personal observation of facts, and a decided mental effort to derive just inferences from that kind of *circumstantial* evidence which such facts afford in regard to their affinities. Experience has satisfied me that 'Structural Botany' may be more conveniently and extensively employed than any other branch of natural science, for strengthening the observant faculties and expanding the reasoning powers of children in all classes of society."

He further says, † —

* Illustrations to be employed in Practical Lessons on Botany, adapted to Beginners of all Classes. Prepared for the South Kensington Museum, by the Rev. Professor Henslow London: Chapman & Hall. 1858. 8vo, 31 pp.

† p. 28.

"Our present object has been to deal merely with the *rudiments* of that department of the science which seems, above all other branches of natural science, best adapted for *educational* purposes. These are, indeed, replete with difficulties hard to be overcome by inattentive, unobservant minds, but can be mastered without more than ordinary, wholesome painstaking, even by young children."

The "wholesome painstaking" here referred to is thought to be an important element of success in oral teaching. The pupil is not to be a passive recipient. The teaching is not to be a "pouring in:" it is simply giving the thirsty a chance to drink.

The fact is often deplored that some pupils make only an indolent and trifling use of the information given them by their teachers. Is it not a pertinent question, whether the fault may not arise from the unwise manner in which the information is imparted. Is it not too often *given* to the pupil, without any exertion of his own? Lavish gifts cannot make the recipient thrifty: they tend to make him a spendthrift. A possible danger of oral teaching, and much other teaching, for that matter, comes from this very source; namely, an injudicious giving of what should be earned. To guard against this danger in the limited field now before us, every teacher should clearly understand what facts are within the pupil's reach, and which he must acquire by work. But there are facts which lie at the side of the path pursued in the study, and which may be freely furnished by the teacher, if they heighten interest in the task. If they fail to increase the interest, or if they distract in any way, it is because they have been injudiciously selected, or presented at an unpropitious time. Let it not be forgotten that oral teaching is not like cross-tag, a game in which the object pursued must be abandoned for the first thing which comes between.

For the purpose of assisting teachers in their work, this little guide has been made as plain and as full as the narrow limits allow.

The cultures and experiments, of which details are given, can be managed in any school-room, without encroaching seriously upon the leisure of a faithful teacher. The care of the growing plants, and the daily observations of changes in their form and kinds of work, should devolve upon one or more of the pupils. Even the slight errors which may be at first made by the young observers and experimenters, and the trifling failures which will result therefrom, can be turned to good account. The time occupied by most of the cultures is so short that frequent repetitions will be found practicable and desirable; and the discrepant results will often furnish fresh and interesting material for study. The appliances which are here recommended are of the most trifling cost. Even simple lenses are not absolutely required for any of the studies here suggested.

To anticipate a question often asked, it may be said that the treasuries of interesting facts in Botany upon which a skilful teacher can draw at discretion in talks about plants are very numerous. Besides the American treatises referred to in this guide, the following may be mentioned: —

LESSONS IN ELEMENTARY BOTANY. By Prof. Oliver. Macmillan & Co.: London and New York. This is a duodecimo volume, based upon the manuscripts left by Prof. Henslow. This would answer every purpose.

A SYSTEM OF BOTANY. By Le Maout and Decaisne. Translated from the French by Mrs. Hooker. A quarto volume of about a thousand pages.

A CLASS-BOOK OF BOTANY. By Prof. Balfour of Edinburgh. An octavo of about a thousand pages.

THOMÉ'S BOTANY. Translated from the German by A. W. Bennett. An excellent translation of a very useful book.

NOTE.

The six botanical lessons in the Teachers' Course in Science were given on Saturday afternoons, in December and January. Each of the five hundred teachers was provided with a tray in which had been previously arranged the specimens required for the demonstration. For instance, the first lesson treated of the comparison of seedlings. The tray before each listener held fresh specimens of the following plants in three or four stages of development, — bean, corn, pea, morning-glory, sunflower, wheat, and flax, together with soaked seeds of a few other plants. These specimens formed the basis of the practical lesson. Although the Guide adopts the course marked out for the sequence of the lessons, the following pages are *not* lecture-notes.

CONCERNING

A FEW COMMON PLANTS.

PART I.

I. SEEDLINGS AND SEEDS.

1. A STUDY OF THE PARTS OF ONE SEEDLING, AND THEIR RELATION TO THE PARTS OF A SEED.

A COUPLE of quarts of clean sea-sand in small flower-pots, or in shallow glasses, or in deep plates, will answer for the garden. The best seeds to begin with are beans and peas. The variety known as Horticultural Bean is large, and adapted to the purpose; but common White Beans will do about as well. Any of the ordinary varieties of Garden Peas may be employed. Two ounces of beans and one ounce of peas will be an abundant supply.

Let the pupils plant a dozen seeds of each sort half an inch deep in the moist sand, and place the flower-pots containing them on a table where the temperature will be about 65° or 70° Fahrenheit. It is a good plan to have the flower-pots covered at first by a pane of glass, in order to keep the sand moist. The pupils in charge of these cultures should take good care lest the sand becomes dry. When the seedlings start, which will usually be in two or three days, a second lot of seeds should be planted, and in two days more a third. The care of the seedlings ought to fall upon the pupils, and not directly upon the teacher. It will be generally found that this trifling care is willingly assumed. At the end of a week or ten days, the seedlings will all be growing well. When the largest seedlings are four or five inches high, the suite of specimens will range from seeds just starting up to those with three or more green leaves. To complete the set, let a dozen seeds of both kinds be soaked in water, a day before the first systematic study of the plants. The bean-plants are to be carefully removed from the sand, and arranged by the pupils, who will place them in a series running from the largest down to the smallest, the latter being, of course, the soaked seeds which have not germinated.

First series.

With the series before him, the pupil may be left to himself to study out the differences and the points of likeness; but, in general, it will be found better for the teacher to guide the work by asking a few simple questions, *which must be answered by an examination of the plants*. The questions may first bear upon the differences between the largest, the middle-sized, and the smallest plants, in order to bring out the changes which have taken place by growth. It will be seen at once that the pupil begins to match the parts which correspond to each other, and that he can identify the parts of the seedlings with their rudiments in the seed. He will trace back the roots of the plants to the tip of the cone-like body in the seed; the shrivelled and greenish seed-leaves are seen to be the withering halves which made up the bulk of the seed; the stem below these and the stem above, with its green leaves, are identified with their promise in the seed itself. He will see for himself how the seedling escaped from its integuments, and in what order its parts have successively appeared.

It is a good plan to have a few other seedlings of the same sort raised in a slightly different way; namely, upon wet paper. These seedlings are wholly free from sand, and may serve to make the series a little more complete. For paper planting, use thick blotting-paper on a pane of glass. The paper is to be thoroughly moistened with warm water, and upon it a few seeds of each kind are to be placed. These are to be covered by a moist sheet of paper like the lower one, and the whole kept warm and damp. A damp sponge, or wet cotton-batting, or moist sawdust, would be just as good a support for the seeds: the seeds need warmth, moisture, and access of air, and these conditions are furnished by any of the materials mentioned; but the sand and the paper will be found in practice to be most convenient and cleanly. Another method of raising the seedlings may be mentioned at this point. After the seed has sprouted on wet paper, suspend it carefully by a thread, or upon a perforated card, over water in a tumbler or glass vase, so that the roots dip beneath the surface, while the seed-leaves remain held above. The roots will spread through the water, and the leaves will expand in the air. An acorn or a grain of corn treated in this manner will be watched with great interest.

When the pupil has made himself familiar with the development of the seedling beans, and has compared their parts with the corresponding parts of the seeds, he is prepared to examine in the same way the seedlings of the pea. The sequence of points observed may be the same as before, but never let any order degenerate into a monotonous routine.

Second series.

2. COMPARISON OF TWO SEEDLINGS.

After this examination has been made, the comparison of the plants of bean and pea is to be undertaken. In some particulars the plants resemble each other closely, in other characters they are very different. The differences and the points of likeness are all to be brought out clearly, so that the following questions can be answered from the student's examination of the plants: —

1st. What are the differences between the parts of the larger and the smaller plants of the same kind?

2d. What are the differences between the two kinds of plants, the seedling bean and the seedling pea?

3d. What do the seedling bean and the seedling pea have in common?

Each of these questions must of course be much divided, in order to ascertain whether the whole subject has been thoroughly examined by the pupil. The character of the subordinate questions must be carefully adapted by the teacher to the capacity of the particular class of pupils. Just at this point, it must be said that the task of observing, comparing, and judging, may be made attractive by the teacher, or it may be made irksome, depending on the kind of questions asked. The child will be interested in the work, if it is not made too easy, if the questions are so designed and arranged as to stimulate curiosity instead of wearying the mind.

It will be asked by some teachers, whether it would not be well to furnish technical terms to the pupils at the beginning of their study. The late Professor Henslow believed that the ordinary botanical adjectives and nouns should be employed at the outset. His views upon this subject are very clearly stated in the following extract from the educational work previously referred to: —

"In order to secure a beneficial result of this sort, [that is, to strengthen the observant faculties and expand the reasoning powers of children,] we must not avoid the use of certain technical expressions, however pedantically unnecessary they may appear to persons unacquainted with their importance and unaccustomed to their use. Scientifically accurate ideas must always be conveyed either by entirely new words or by peculiar technical meanings assigned to old words. Botanists employ both methods. Some of the most important technical terms have not been judiciously selected. Some are too long, others harsh and ungrammatical. But the few terms to which these objections apply cannot be satisfactorily dispensed with. They are thoroughly established, and are, in fact, much more readily learned than might be imagined."

Professor Henslow's first step in the instruction of his class of children was to place before them the following words to be correctly spelled from memory: —

CLASS.	DIVISION.	SECTION.
(I. *Exercise.*)	(II. *Exercise.*)	(IV. *Exercise.*)
1. Dicotyledons.	1. Angiospermous.	1. Thalamifloral.
		2. Calycifloral.
		3. Corollifloral.
		4. Incomplete.
	2. Gymnospermous.	
	(III. *Exercise.*)	
2. Monocotyledons.	1. Petaloid.	Superior.
		Inferior.
	2. Glumaceous.	
3. Acotyledons.		

One part of each Monday lesson consisted of a Hard-word Exercise. "Two or three words named one Monday are to be correctly spelled the next Monday."

This must be called an extreme method, and, at first sight, it would be called an impracticable one; but, judged by its results, it is admirably adapted to some classes of pupils. (In a most useful adaptation and amplification of Professor Henslow's system of botanical teaching, Miss Youmans * has pursued a very judicious course. The technical terms are not thrust upon the student: they are introduced only as they are needed in recording the results of observation.) In oral instruction, however, it would seem to be better to let the technical terms come only when they can be of assistance to the student, and felt to be aids in his work. Technical words are short-cuts across tiresome circumlocutions. Children can be early made to feel that much is gained by their appropriate and timely use; but in the

* The First Book of Botany, designed to cultivate the observing powers of children. By Eliza A. Youmans. New York.

simple studies of plants here recommended the employment of technical substantives and adjectives can be for the most part avoided. In the case of the youngest pupils, this avoidance of such terms should be regarded as very necessary: the term must never come between the child and the thing or the phenomenon studied.

3. VERY DIFFERENT SEEDLINGS COMPARED WITH EACH OTHER.

To procure material for this purpose, plant in the manner before directed a few seeds of Squash, Morning-glory, and Water-cress, and a few of the seed-like fruits (commonly called "seeds") of Sunflower, Indian Corn, Four-o'clock, and Wheat. The cress-seed need not be placed below the surface of the sand. When any of the seedlings have fairly started, let a second set of the seeds of the same be sown, and, when the latter have sprouted, plant a third set. Each kind of seedling is to be examined after the manner fully detailed with respect to the bean, and all its parts are to be matched with the parts seen in the seed. Afterwards let these different kinds of seedlings be carefully compared with each other, and with such seedlings of the bean and pea as may have been left over. The differences in development are plainly seen; the points of likeness are not so obvious, but their recognition must be insisted upon. The child must be led by questions, never by statements, to see the resemblance between the seedlings before him. If this is honestly and patiently tried, it will be found that the child, by a decided mental effort, will detect

Third series.

what the seedlings have in common. He will see that in some cases the seed-leaves have become pretty good green leaves, that in others they are shrunken and greenish, that in others they do not come into the light. He will notice also differences in number as well as shape. By adroit questions, the teacher can lead the pupil up to the examination of what the seed-leaves can possibly be for, and without furnishing any aid to the investigator elicit at last the suggestion that they may be food-leaves for the young plant. Some young plants begin to earn their own living very early, others have a good store laid up for them, and this store of food is put in different places, and is of different kinds. Let the food be searched for in the Four-o'clock and Corn and Morning-glory; and, when the pupil has made out this for himself, the other kinds of food which seedlings have may be described as the teacher may have leisure. The food of the vegetable-ivory seed ling, which is as hard as ivory itself; the food of the nutmeg-seedling, the aromatic substance which makes up the bulk of the seed; and other sorts of food, — can furnish material for a talk which would not be uninteresting even to the dullest pupil. The oily food of flax-seedlings can be shown in some crushed flax-seed placed between dry blotting-paper. The linseed oil will appear in the paper. The very different food of wheat-seedlings may be exhibited best in very fine flour. The flour is to be slightly moistened in the hand and kneaded until it becomes an homogeneous mass. Upon this mass pour some pure water, and wash out all the white powder until nothing is left except a viscid lump of gluten. This is the part of the crushed wheat-

The food of seedlings.

grains which very closely resembles in its composition the flesh of animals. The white powder washed away is nearly pure wheat-starch. Of course the other ingredients, such as the mineral matter and the like, might be referred to; but the starch, at least, should be shown. When the seed is placed in proper soil, or upon a support where it can receive moisture, and can get at the air, and still be warm enough, a part of the starch changes into a sort of gum like that on postage-stamps, and finally becomes a kind of sugar. Upon this syrup the young seedling feeds until it has some good green leaves for work; and, as we have seen in the case of some plants, it has these very early.

The starchy food in seeds keeps good a long while, and seeds having such food will grow, even after they have been kept for many years; but the oily seeds are apt to spoil much sooner. The food in the seed is packed away in minute compartments (cells), and is used by the seedling in making new compartments for different kinds of work. How the starch was made for and put into the seed, and how it is used in growth, will be seen later on.

II. HOW THE PARTS OF FLOWERING PLANTS HELP ONE ANOTHER.

This guide is devoted to the consideration of only the flowering plants, those which have true blossoms and bear seeds with plantlets in them. Therefore, mosses and their kindred are not now treated of. If any of the seedlings spoken of in I. 1, 2, or 3, be carefully examined when it has a few green leaves, it will be seen to be made up of roots, stem, leaves, and a few delicate plant-hairs. Now these are all the parts that any flowering plant ever has: the thorns and tendrils, and showy leaves and blossoms, and all the parts of every blossom, are only modified forms of one or more of the four parts or members just spoken of. This is the statement, made abruptly and in few words, of the accepted theory of plant structure. Of course it is difficult to bring such an abstruse notion before a child; but, inasmuch as the notion itself is of great assistance even in a very rudimentary study of common plants, the endeavor ought to be made. The attempt has been successfully made in the following manner: The several series of older seedlings with plenty of leaves and good roots are to be placed before the pupil with some such question as this: How many times are parts which are made up of *a joint of stem, and a green leaf above*, repeated in each plant? In one, there will be six or more of these repeated parts; in another, only two or three; in another, perhaps only one. That the "repeated parts" differ greatly in their shape has been noticed in the study of the seedlings; that the repeated leaves have different kinds of work was also then made plain. If this is clearly understood, the pupil may be told that these "repeated parts" are *helping parts* or *helpful parts*. These parts are mutually helpful: they help one another. The whole plant is made up of just such parts, which have taken different forms for different kinds of work, as, for instance, in the leaves of the pea. It has been found that children grasp this notion of the helping-parts very readily, and hold it very firmly, as an aid in

Helping parts.

their further progress. (Although it would be advisable in the case of the older pupils to bring out clearly the notion of the phyton, or phytomer, the internode of stem with its node and leaf, it is generally better to state that the helping parts are joints of stem with the leaf which belongs to it, and that any one of these helping parts may have roots and hairs, and, further, that they take very different forms for different kinds of work.)

The seedlings have shown these helpful parts, arranged in regular order. From the lowest of the helpful parts of the bean, the root started; but, in the Indian corn, roots have started off also higher up. Again, they have plant-hairs in different places. Upon the youngest rootlets of the wheat or corn planted on wet paper, the hairs are very abundant; and there are some hairs scattered on the leaves of the bean. These roots and the hairs are to be examined later.

The succession of the helpful parts will be noticed best in slips of the common plants, "Wandering Jew," or Tradescantia, Heliotrope, and Bouvardia. In the case of the Tradescantia, the growth of a slip or cutting in moist sand, or with the lower end in water, is very instructive: roots grow from the lowest of the helpful parts, and furnish the food needed in solution, new leaves expand above to get food, as we shall see, from the air; and thus a separate, self-supporting colony is established. A flowering plant is a community from which many such colonies might be removed.

Communities and colonies.

Next, the pupil should be led to study the question: Where do these helpful parts come from? For this purpose, a good branch of Horsechestnut, stripped of its leaves, but having large buds, will be found useful. This should be studied without any help from the teacher; in fact, if any aid is asked for, it may be accepted as an indication that the pupil has made too great haste and to very little purpose. A child who has patiently gone through the examination of the seedlings will be able to see that the bud-scales are leaves, changed in form, to be sure, but not so much as some of those in the seedlings, and that these leaves are regularly but closely packed upon a tiny space from which the stem is to grow in the spring. In many of the larger and more plump buds of horsechestnut, the rudimentary flower-cluster can be seen. Next, ask the pupil how old a fragment of a branch with a terminal bud is; and, if he has fully grasped the idea that a bud is the promise of a branch, he will count back and see how many rings of bud-scale scars there are on the stem. The clusters of rings mark the years.

In the buds of Lilac, the four-sided character of the bud will probably attract attention. Any of the large buds of our deciduous shrubs and trees will present many interesting features for examination; namely, the relative size, *position normally in the upper angle which a leaf makes with the stem*, the protective scales or outer parts, the mode of packing, and the presence or absence of flowers within. It must not be supposed that the subject of buds can possess as much interest for younger as for the older pupils; nor will it be found for the latter as interesting as the studies of seedlings and flowers. But, nevertheless, with the exercise of some tact, good use can be made of the abundant material for study which our common buds afford. In winter, or better at the approach of spring, shoots with strong buds can be kept fresh for a long time by dipping the lower end of the cutting in water, and sometimes the buds will develop good leaves. Shoots of Rhodora and Cassandra having flower-buds will bloom after a few weeks' exposure to the warm air of a room, provided the cut ends are not allowed to dry. And this brings up the allied subject of flower-buds and what they teach. Procure for the purpose of this study good flower-buds of any common house-plant; and with these give the pupils large leaf-buds of Lilac or Horsechestnut for examination and comparison. Most of them will soon remark upon the regular though different arrangement in the various parts of buds, and recall the fact that a bud is the promise of a branch. The application of this to the case in hand will force the conclusion that, since whatever springs from a bud is some sort of a branch, a developed flower from a flower-bud must be a branch too. And so it is. The helpful parts are here arranged in a very regular manner, and many of them are greatly changed in form and in work. From this subject, to be examined fully in another place, we pass naturally to the development of buds underground. A leaf-bud — that is, an incipient stem — develops by lengthening the distance between the successive leaves. Under ground, in firm soil, such buds develop at great disadvantage; and the stems soon become more or less distorted, the degree of distortion depending somewhat upon the character of the soil in which growth takes place. The extremes are to be found in Beach Bind-grass (*Calamagrostis arenaria*), which has long internodes or joints of stem, and such plants as *Iris*, or Blue Flag, and Solomon's Seal. In not a few cases, the growth of the underground stem gives rise to very curious forms, which may be puzzling at first; for instance, the solid bulb or corm of crocus, and the thickened tip of the underground branch of potato, namely, the tuber itself. The "eyes" of the potato are merely disguised buds which have a good stock of food behind them. Potato-planting is colonizing, in which the tubers are the colonies separated from the home community. A very bad kind of such colonizing takes place when the underground stems of Witch-grass (*Triticum repens*) are only broken off, but not taken out of the soil, in hoeing the ground. The helpful parts are detached from each other, and each fragment serves as a starting point for a new plant. In grafting and in budding, one or more groups of colonies of helpful parts are removed, not to soil where they would have at once to shift for themselves, but to a kindred plant, which furnishes proper nutriment from the very first.

Thus, it will be seen that from a few kinds of buds children may learn a good many things. They will clearly apprehend the notion that buds consist of helpful parts which are packed away in a rudimentary form; and they will, after a little, recognize buds under their many disguises in bulbs, bulblets, and the like. When they have made this out, they will next proceed to learn that buds are formed *as a rule* in the axil * of leaves, and that whatever grows from a bud is a branch of some sort; all of which facts can be learned by observation, and not merely told to the pupil.

* That is, the upper angle formed by the leaf and the stem.

III. ROOTS.

1. THEIR MODE OF GROWTH.

As we have seen in the examination of seedlings and cuttings, roots can start from different points of the stem. In some cases, they can arise from the leaf-stalk or even from the leaf-blade itself. The root, whatever its origin in any case may be, grows in length only in one way; namely, at a point just behind its very tip. This growing point is usually protected by a peculiar cap, which insinuates its way through the crevices of the soil. If roots should grow as stems escaping from the bud-state do, — that is, throughout their whole length, — they would speedily become distorted. But, since they grow at the protected tips, they can make their way through the interstices of soil, which from its compactness would otherwise forbid their progress.

How roots grow in length.

That roots grow in length only in this way can be easily proved by a simple experiment, which can be left to the management of any pupil. Let a young seedling of corn be grown on damp paper in the manner described in I. 1, and, when the longest root is a few centimetres long, let it be marked very carefully by means of India ink or purple ink, put on with a delicate camel's-hair pencil, by lines just one centimetre apart. The plants thus marked are to be kept under favorable conditions with respect to moisture and warmth, so that growth will be as rapid as possible. The marks on the older part of the root will not change their relative distance, but the mark at the tip will be carried away from the one next to it, showing that the growth has taken place only at this point. Such experiments as the one just described are perfectly practicable for all classes of pupils except the very youngest. How far the details of these experiments should be suggested to the pupils, or rather how far they should be left to work out the problems for themselves, is a question to be settled by the teacher in each case. The better plan generally is to bring the problem in a very clear form before the whole class, or before the whole school, and ask whether anybody can think of a way in which it can be solved; for instance, in this case how can it be found out whether roots grow only at their tip or throughout their whole length. If the way is thought out by even a single pupil, the rest will be interested in seeing whether the plan will work successfully. The conditions which govern the growth of roots in length may be made a very attractive study, by leading the pupils who are for the time in charge of the experiments to *race* the root-tips. The quick-witted experimenters will soon learn the best degree of warmth and the requisite amount of moisture for improving the time made by the root-tips under their care.

How roots branch.

The branching of roots never seems very symmetrical at first sight, but that there is sometimes an obscure order underlying the arrangement can be made clear by the water culture referred to under I. 1.

Concerning the thickening up of roots as storehouses of food, nothing will now be said.

2. THEIR WORK.

If the roots of the youngest seedlings of wheat or flax are carefully examined, they will be seen to be covered, except near the tip, by a very delicate fuzz made up of extremely fine hairs. These are the root-hairs, which serve to take up the water-food for plants. They are so exquisitely delicate that the slightest touch crushes them; and, if the plant is lifted from the soil, all the root-hairs are left behind, or else a few hold fast to finer particles of soil which are brought away.

Root hairs.

Of course, a microscope is very necessary in any careful examination of root-hairs; but the hairs can be seen without one in the cases mentioned, and in some others, where they are looked for carefully. The pupils may be told that it is these root-hairs, and not the very tips of the roots, which absorb water. This can be studied practically by the older pupils in the way pointed out by Ohlert, a German school-teacher, who first published, in 1837, an account of root-hairs. The tips may be carefully removed, and the wounds painted over, and the roots be placed again in water, where the hairs can have a chance to absorb, if this is their office.

Root-hairs are found only on the newer parts of roots; and these are therefore the only active absorbents of dilute aqueous solutions.

IV LEAVES.

The dilute solutions just spoken of are carried through the older parts of the root up to the stem, and through the stem to the leaves and other green surfaces. Here some very interesting changes take place, a few of which can be made plain, even to young children, if they have faithfully worked out the subjects up to this point.

Green leaves are generally so constructed that water evaporates readily from their substance. This exhalation (although it is something more than mere evaporation) can be shown by a very simple experiment, devised by Professor Henslow, and which will be described in the words of Professor Oliver's Botany, p. 15:—

"Exposure to sunlight, as well as dryness of the air, has to do with this evaporation of water from the leaves. Take six or eight of the largest, healthiest leaves you can find, two tumblers, filled to within an inch of the top with water, two empty, dry tumblers, and two pieces of card, each large enough to cover the mouth of a tumbler. In the middle of each card bore three or four small holes, just wide enough to allow the petiole of a leaf to pass through. Let the petioles hang sufficiently deep into the water when the cards are put upon the tumblers containing it. Having arranged matters thus, turn the empty tumblers upside down, one over each card, so as to cover the blade of the leaves. Place one pair of tumblers in the sunshine, the other pair in a shady place. In five or ten minutes, examine the inverted tumblers. That exposed to the sun you will find already lined with dew on its cool side, while that kept out of the sun is still nearly or quite clear. It is manifest, therefore, that evaporation from the leaves must be not only rapid, but considerable in amount, when plants are exposed to the sun or a dry atmosphere."

By the evaporation, or transpiration, as it is called, which goes on from green leaves, the dilute solutions which have been raised to the foliage become more concentrated. The transpiration is governed largely by delicately balanced valves, which are chiefly on the under surface of the leaves.

Whether it is best to try to explain to the pupils the structure of these valves, or stomata, must be left to each teacher.

It would seem advisable to pass by the subject untouched, unless the teacher has become reasonably familiar with it by practical microscopical study of leaves. For a teacher to endeavor to explain the complex structure of the leaf, without having seen it for himself, is open to the same objection which could be urged against the attempted explanation of complicated machinery by one who has never seen it, but has heard about it. What is here said in regard to stomata applies to all the more recondite matters connected with plant structure.

Leaf-work.

Within the tissue of green leaves, there can be found under the microscope granules of a leaf-green substance called chlorophyll. Under the influence of sunlight, carbon dioxide, a gas which exists as an impurity in the atmosphere, and which is readily taken up by green leaves, undergoes, together with the water within the leaf, changes which end in the formation of starch or something very much like it. While such an operation is going on, oxygen is given off by the leaves. The relations of oxygen and carbon dioxide to animal respiration are to be pointed out to the pupils; and it is to be made clear that the evolution of oxygen from green leaves goes on only in the light. In all its kinds of activity, except that of leaf-green in sunlight, the plant takes in oxygen and gives off carbon dioxide. But the work of leaf-green in sunlight, namely, the conversion of inorganic matter into organic substance, is the chief work of the common plants about which we have been studying. This work is *assimilation*. The description of this process, and its relations to growth, are very clearly stated in Dr. Gray's "How Plants Grow," and in his "Lessons in Botany."

The assimilated product made by green leaves in sunlight is stored up in many forms and in many places, such as roots, stems under and above ground, leaves, and seeds. It is used for many purposes, chiefly the following: making wood, and the like, building up new parts, forming flowers, and making seeds. Some of these kinds of work are to be briefly examined.

To sum up the work of green tissues, whether on the stem or in leaves themselves, it may be said that they lift dilute solutions from the roots to the light and air, there concentrating them; that they are the factories where starch or something very similar is made. To point out the many beautiful adaptations to these purposes by different exposures, positions, and shapes, will furnish to every teacher conversant with the facts very abundant material for interesting talks.

If a school-room window has plenty of plants with green foliage, some of them will exhibit movements of leaf-stalks and stems in response to light, and these movements are well worth watching.

Lastly, it may be said that, although plants give off carbon dioxide in the dark, the amount is trifling, and in the case mentioned above cannot seriously affect the atmosphere of the room. The windowful of plants can do no harm.

V. SOME OF THE RELATIONS OF PLANTS TO THE SOIL.

WHEN the trunk of a tree or the stem of an herbaceous plant is carefully burned in the open air, there remains behind a certain amount of rusty-gray ashes. This substance represents the mineral matters taken in solution by the roots, and now changed somewhat by combustion. Some plants contain more of this mineral matter than do others, but all of them have a trace; and there is a substantial agreement in the chemical elements of the ash of different plants. Some of the elements which have been detected in the ash are Iron, Potassium, Calcium, Magnesium, Phosphorus, and Sulphur. These exist in composition in the ash,—for instance, the Potassium is there a carbonate; but as to the manner in which they existed in the plant, and how they were there compounded, authors are not exactly agreed. Nor is it precisely known what part each plays in the life and health of the plant. There is good reason for believing that Iron is indispensable to the efficiency of chloro-

Wood-ashes.

phyll, and that the salts of Potassium have much to do with the production of starch. Besides the substances just mentioned, some compound of Nitrogen is essential to the growth of plants; and this is furnished likewise through the roots. If, therefore, it is desired to have plants grow in a healthy and vigorous manner, they must not only be placed under the requisite physical conditions, but good food in proper amount must be furnished.

Plant-food.

Plants, as we have already seen, obtain their carbon from the carbonic acid of the atmosphere. The soil furnishes other kinds of matter used as plant-food. Although the germinating seeds can thrive in sand for a while, it is because they can use the good store of food laid up for them by the plant on which they ripened. And, even after this store is gone, they will do pretty well for a time; but sooner or later they need something better than sand to live in. Now sand is a very good mechanical support for sprouting seeds, if the seedlings are to be studied; for it is the most cleanly. But, if the plants are to be raised from seed for the purpose of studying them in all their stages of growth, it will be better to procure some good soil at a florist's greenhouse. Flower-pots six or eight inches in diameter are large enough for the cultivation of such plants as are adapted to school-room study. In flower-pots of this size, it is perfectly easy, for instance, to raise good plants of Morning-glory to exhibit the twining movements of stems, and Sensitive Plant to demonstrate the "sleep," "waking," and sensitiveness. The plants may not prove to be as symmetrical as those raised by an accomplished florist; but they will answer a good purpose in the school-room, for they are plants which the pupils have watched from the beginning of the growth. To show how small a part is taken in certain cases by the mineral constituents of plant-food, it may be well to call to mind one of the earliest experiments upon the subject of vegetable nutrition.* Van Helmont placed in a proper receptacle exactly two hundred pounds of carefully dried soil, and then planted therein a willow, which weighed just five pounds. The soil was enclosed by a cover so that no dust from outside could reach it; and it was kept moist with enough water as occasion required, for five years. At the end of that time, the willow was removed, and the soil separated carefully from the roots. The willow weighed then one hundred and sixty-four pounds; but the soil, again thoroughly dried, as at first, had lost only two ounces! Although the experiment was not conducted with the exactness which characterizes modern research, it was a very excellent one for the time in which it was performed. It must be added that Van Helmont erroneously concluded that the plant had taken all its nourishment from the water, whereas we know to-day that the plant obtains from the atmosphere a large part of the material out of which its structure is made. Before entering upon the use of plant-food in building, it is best to glance at the different ways in which a part of the elaborated substances are held in reserve.

Van Helmont's experiment.

* From page 493 of Geschichte der Botanik, by Professor Sachs. The experiment was made about 300 years ago.

VI. FOOD HELD IN RESERVE.

We may speak of the carbon-dioxide taken from the atmosphere, the water from the soil, and the mineral matters therefrom obtained, as the food of the plant; but it is better on all accounts to speak of the first elaborated matter formed in the foliage under conditions now described as the proper food for the nutrition of the plant. Some plants are like spendthrifts. They use up all this food as fast as it is made, and do not lay up much or even any of it. The annual plants treasure up a little of this food in the seeds, but plants which are to live through more than one year keep more or less food in reserve in some safe place.

Starch.

The food may be stored up as starch, as in most of the thickened fleshy roots and underground stems or branches, or in stems above ground, or even in leaves. The starch is packed away in the form of an impalpable powder consisting of granules of such characteristic form that its source can be easily identified by the microscope. Sago and tapioca are starches which have been carefully separated from the substance of the plants which produced them, and the former has become somewhat changed by the process of manufacture. The laundry starches are largely from potato, or from wheat. Starch in woody stems like that of the maple in early winter is lodged in the less dense part, and here it is ready to be changed into syrup at the coming of spring. Starch can be very readily detected by the blue color which it gives when brought in contact with a dilute solution of iodine.

Another less usual form in which food is stored in reserve is sugar. This is its form in the stem of sugar-cane, and in the fleshy root of the sugar-beet. When sugar is properly made from these two sources, it is impossible to distinguish between them. Of the forms of sugar other than cane sugar, as it is called, nothing can now be said further than to point out their occurrence in fruits and exceptionally in stems. There are still other forms in which food is packed away in plants ready for use; but their consideration would not be desirable in this short guide. It is enough to note now that the reserve material is packed safely, and when wanted it is within reach. And next it must be seen how it is used in building, or in growth.

Sugar

VII. PLANT-GROWTH IN GENERAL.

Plant structure consists of minute cells of different shapes, variously arranged and compacted. Plant growth consists in the production of new cells, and their increase in size, at the cost of material prepared by foliage.

Of course, this elaborated material must undergo many changes before it can be used for the building up of new cells. So far as shapes of cells are concerned, it is now necessary to refer to only three principal forms: 1st, spherical, or nearly spherical, these are generally compressed somewhat into polyhedrons by contact with other cells (as in the pith of Elder); 2d, elongated cells, which may be either cylindrical or spindle-shaped, that is, tapering at

Shapes of cells.

both ends (as in wood-cells); 3d, flattened cells of many sorts.

When the wall of a cell is first formed, it is very delicate. In most cases, it speedily undergoes changes in its thickness and toughness. The thickening is seldom even. Its irregularities therefore give rise to dots and pits and pores, and many curious markings; but these can be seen only under the microscope, and need not be further spoken of here. It is enough to observe now that the thick-walled cells in plants are generally of the second sort; that is, they are elongated. They become sometimes very long and tough, and have only a small cavity, or none at all, within: these are called *fibres*. The other long thickish-walled cells, which are rather more brittle, are, with all their varieties, called wood-cells. An interesting form of wood-cell gives rise by its development to what are known as ducts. The cells are formed in chains, and the partitions between the cells break down, leaving a jointed tube or duct. Another very common form of wood-cell is spindle-shaped and flattened.

The cell-wall.

To trace out the development of all these fibres and wood-cells, from the simple kind from which they rise, is a task wholly foreign to the present work. It is enough to state that these cells, which in their varied forms give rise to the complex fabric of plants, are marshalled in definite order. Only a few of the more frequent modes of arrangement are now to be mentioned, and these only for the purpose of showing that a study of our common woods and barks, even without the aid of a lens, may be practicable in our schools.

Fibres and wood-cells.

Plants which do not have woody stems are not at present to be considered. The herbs which have only very imperfectly formed wood, and the plants whose tender soft-wooded stems are killed by the frost, are to be left out of account. Any shoots of our trees or hardy shrubs with thick bark are available for illustration of the present subject. Willow, Poplar, Elm, Horse-Chestnut, Maple, or Ash will answer perfectly. If the newest part of the shoot is compared with that produced two or three years before, it will be seen to differ in many respects. In the latter, the pith is less conspicuous, there are other rings outside the first circle of wood, the bark has a firmer lining and a rougher exterior. Compare this older shoot with one which is five or more years older still, and the differences are more manifest. The outside layer is made up of a sort of cork which is beginning to crack here and there, giving to the bark a very irregular surface. This outer layer consisting of cork might be taken from the plant without any injury, if carefully done. The cork-bark of commerce, a very thick layer of this kind, is taken off from live trees of the Cork Oak in this way; and then the trees produce another belt of cork, to be removed in a few years more. The number of years can be easily counted from their record in the compact layers.

Cork.

The inside layer of the bark consists of fibres which are frequently so conjoined as to form a kind of lace, fine in the lace-bark of the West Indies, coarse in our Linden. The fibres of Linden constitute bast-matting or Russia-matting. The fibres of hemp for cordage, of jute and flax ready for spin-

Bast.

ning, are bast-fibres which have been detached from the rest of the plant either by mechanical means, by chemical processes, or by what amounts to pretty much the same thing as the latter, decomposition. With the one marked exception of cotton, which consists of the plant-hairs on cotton-seeds, the textile fibres of the arts are bast-fibres. Indian Corn, Bamboo, and Rattan have their bast-fibres, with groups of wood-cells and ducts, scattered all through the stem, but ending for the most part at its very outside, here forming a dense cylinder not separable from the rest of the stem. In these cases, the distinct clusters of bast-fibres and ducts are packed firmly by means of spherical cells. The bast-fibres in the thicker leaves of plants of this sort — for instance, Century Plant and New Zealand Flax — are easy to prepare for use as cordage, &c., and they are strong and good.

Wood.

For the present purpose it may be said that the wood used in the arts is of two kinds, namely, that which consists only of wood-cells, properly so called, and that which has also ducts either large or small. The wood of the coniferous trees has no ducts, except sometimes at the very centre: it is made up of spindle-shaped cells, which are more or less flattened. Such woods as Oak, Ash, and Elm have proper wood-cells and ducts besides, in many instances the latter are very conspicuous, and give to the cross-section of the stem an open, porous look. Certain differences in the character of the wood-cells and the ducts, probably depending upon varying pressure exerted by the bark, are observable between those formed in summer and in autumn. These differences are often clearly marked, and give rise to the well-known rings of wood. The thickness of the rings denotes the amount of wood made during a single year. The new wood is made by the multiplication of closely packed cells which lie between the wood and the bark. These layers of closely packed cells have a double work. Upon one side they build new wood, on the other side they lay down a new film of inner bark or bast. In the spring, when these layers (the cambium or meristem) begin their work of forming new tissues, they constitute the juicy and sweetish substance found under the bark. The sweetness results from the presence of a kind of sugar which is made at that time from the stored-up starch. Removal of the cambium, of course, prevents the production of any more new wood or bast at the place of injury. Often, however, if the wound caused by its removal is not too grave, it may be healed over by thin films of freshly made cork.

Annual circles.

A very slight examination shows that the width of the year's wood varies considerably in different years, and on different sides of the stem. Moreover, the wood nearer the centre is denser than that just under the bark; the former is the heart-wood, the latter is the sap-wood, and is the last formed. In some stems, the irregularities in the rings are very striking: in one case pointed out by President Chadbourne, the parts of two rings are sometimes confluent. Radiating from a point not far from the centre, many very slender lines run in a somewhat broken manner out to the bark. These are the pith-rays. They lie between the wedges of wood, and, when they are seen

Silver-grain.

in section, appear as shining surfaces. These constitute the silver-grain of wood. Here, then, are two things, each of which will look very differently in different slices of wood. Pieces of wood cut in different ways will be found to be frequently puzzling, but useful objects of study. The student is to identify the silver-grain planes, or the pith-ray lines, and to make use of these in connection with the circles of which they are radii, to ascertain certain facts respecting the specimen. For instance, suppose a small prismatic block of wood, cut from an oak stem which is twenty inches in diameter: it will exhibit on its different sides different exposures of the rings, or cylinders, and the pith-rays, or planes; and from an examination of these it will be possible to detect the place from which the block was taken. The difference in color between the heart-wood (the older) and the sap-wood (the newer), the differences in size between the inner and the outer circles, afford easy marks by which the position of the block with respect to the stem can be ascertained. If the plane sides of the block are not at right angles to each other, the problem becomes more difficult; but it is always an interesting one. Questions respecting the position which a block or a board must have had in the log from which the piece has been cut will generally be found within the reach of most of the pupils except the youngest.

The specimens * which have been furnished to illus-

* Mr. Charles W. Spurr, 522 Harrison Avenue, Boston prepared, for the purpose of illustrating the subject of Veneers 500 packages of excellent specimens of the following woods Tulip-tree or Whitewood, Rosewood, Ash, Oak, Pine, Mahog-

trate the subject of texture of woods are known in the arts as Veneers. These are thin slices of wood, cut for the purpose of displaying the characteristic texture or grain, and which are to be securely glued to cheaper woods. Specimens prepared in this manner exhibit very beautifully most of the features which have been referred to under the subject of circles and silver-grain.

Veneers.

The branches which fall off from decay or are broken off by injury leave roughish projections, which sooner or later are healed over by the subsequent growth of the stem. The buried trace of the branch remains as a concealed knot, and frequently disturbs for a while the regularity of the wood formed in its immediate proximity. When the branches are small and exceedingly numerous, — especially if they are short and hard, as if the buds from which they sprang had given rise only to a blunt thorn, — the disturbance of the layers of wood produces some of the most beautiful of the ornamental woods.

Knots.

When the terminal buds of the main stem and of the branches of our trees expand fully for the season, their growth in length is arrested. The growth of the stem or branches in length in the following year is solely by the expansion of new buds. If two nails are driven into a stem, at a definite distance from each other, that distance will ever afterwards remain the same. It must be remembered, however,

Growth in height.

any, Walnut, Butternut, Maple, Cedar, Birch, Cherry, Elm, and Holly. Many of these were in duplicate, exhibiting both plain and figured texture. The specimens, more than ten thousand in all, were gratuitously presented to the Class by Mr. Spurr that the shape of a tree is constantly changing year after year, from the loss of branches, chiefly the lower and shaded ones, which do not have a fair chance; and so the main trunk appears to carry the crown of branches higher and higher up. The relations of the position of buds to the ultimate shape of the tree, and of the relative strength and vigor of buds to the form at last attained, are easily observed with a little care. It is worth the while of any teacher to call attention to the spire-like and the spray-like forms of shade-trees, and to ask the pupils to compare the grown tree with its plan laid down upon a branch with buds. It is comparing a finished building with the sketch made before it was erected.

VIII. THE FLOWER.

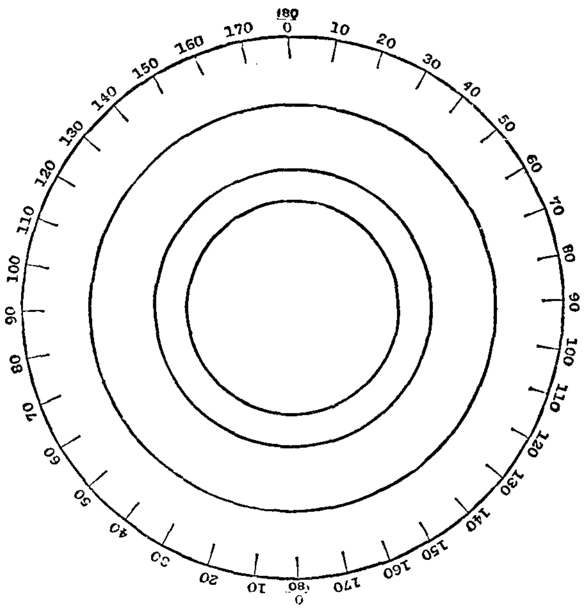
A flower is a branch with leaves for the production of seeds. It is easy to find fault with every definition of so diversified a mechanism as a flower, but the definition just given will answer our present purpose very well. On page 23, it is stated that, "since whatever springs from a bud is some sort of a branch, a flower developed from a flower-bud must be a branch too. And so it is. The helpful parts are here arranged in a very regular manner, and many of them are greatly changed in form and work."

A blossom may be examined from many different points of view: of these, three will now be mentioned.

1. A flower may be regarded as a complicated mechanism made up of simple parts. Considered as a branch,

a flower must be looked upon as a very short one, with the leaves crowded together into circles or into much depressed spirals. First of all, then, it is desirable to separate the parts of the crowded branch a little, so that their relations can be better seen. For this purpose, in ordinary cases, the following plate will be found useful. Begin with a

Morphology.



Crassula, or some good regular flower, and place each part of each circle of the blossom in its corresponding place in one of the circles of the diagram.

For instance, if the flower is on the plan of three, the parts of the outer circle (calyx) must be placed 120° apart; the parts of the next circle (corolla) 120° from each other, alternating with the last; the stamens come next; and, lastly, the carpels, or the fruit-leaves (constituting the pistil); and the members of the circles will have definite relations to one another. On the plan of five, the parts in one circle will be 72° apart; on the plan of four, 90°.

Now suppose we have a complete and regular flower with five members in each circle or whorl. Let the parts be separated, and placed in their proper order on the circles of the diagram, where they will again make up a complete and regular blossom. When this has been done, take away one of the stamens. Has it disturbed the relation of parts? Obviously not: *the place is left.* Next break a stamen in quarters, and replace one of these fragments. It lies in its proper place a mere vestige of a stamen, but the relations of the parts remain the same. What we have thus done with the dissected flower, Nature has done with very many. How to see what parts have been lost, or what remain only as traces, is a very interesting study. This study is much more difficult when the parts of one circle have become disproportionately enlarged on one side, or the parts of two circles have grown together more or less. To strip off these disguises, and detect the hidden symmetry of arrangement, is the attractive task of Morphology.

Analysis of flowers.

For schools, the simpler flowers, of large size, are preferable at first. Dog-tooth Violets (*Erythronium*), Lilies, Buttercups, Laurel (*Kalmia*), Single Pinks, and so on, are good to begin with; and these are to be dissected upon tablets, as above described, and as each part is removed it must go in its corresponding place. There is not an easier method of exhibiting the relations of position of the parts of flowers than the one here recommended. Even young pupils can remove the sepals, petals, stamens, and carpels, — even if they have not been told the names, — and rearrange them in the proper order. After a while, let the names of the parts be given, and these will speedily become familiar. When practice in this has been sufficient, three questions are to be asked concerning every flower thus analyzed : —

1. How many parts are there in each circle, and how are they arranged?

2. How are the parts of the same circle united together?

3. How are different circles united?

The study of flowers for the purpose of answering these questions may be made the best practice in observation which Botany affords. The pupils must be made to understand that, at this period of their progress, no help is to be expected from the teacher : the answers must be found in the flower. To indicate how exhaustive and how far-reaching these three inquiries are, we will apply them to a single illustrative case. 1st, There are five sepals alternating with five petals ; five stamens opposite the petals, and none alternate with them ; more than one carpel, probably five, though the latter fact is hard to make out. 2d, The five sepals are united more than midway ; the petals are united together, hence the corolla is monopetalous ; the stamens are separate ; the carpels are united to form a pistil with a single style and one-celled ovary with ovules in centre. 3d, The stamens are borne on the regular corolla ; the calyx, corolla, and ovary are all borne on the receptacle, and are distinct from each other. Now apply this to the Analytical Key of Dr. Gray's School and Field Book, and it will be found that we can, without hesitation, place the flower under the following heads: Flowering, Exogenous (plan of 5), Monopetalous, Calyx free from ovary, Corolla regular, stamens as many as the corolla-lobes and opposite them, style only one, ovary one-celled, ovules many = Order *Primulaceæ*. The facts elicited by the questions have been gained by the pupil in an analysis like this by independent observation. If the pupil reverses this process, and uses the key in the Botany to ask the questions by, he is adopting a method which tempts one constantly to look ahead to see how "the plant is coming out," as the phrase is.

So-called analysis.

If there is the slightest prepossession in the mind in regard to the probability as to which Order the plant belongs, this will influence the judgment about every point in the analytical key. It will lead, sooner or later, to a weak, careless, unfair, or even dishonest method of work. An analytical key is an artificial device at best, — a sort of pick-lock, to save time. It may be used after, but not before, the three questions above spoken of have been answered; certainly not *while* the questions are being answered. To study a plant and its blossoms, from the point of view of Morphology, is a task of such interest and value for training that it cannot well be overrated. To thread one's way through the mazes of an analytical key, *before* the structure of the flower in hand has been thoroughly mastered, is to deal with a puzzle of little interest and of less profit.

Another method of arranging the answers to the questions proposed on the basis of Morphology was suggested by Professor Henslow, and embodied in Professor Oliver's Elementary Botany. An illustration will suffice:— Schedules.

Organs.	No.	Union of like Parts.	Union of different Circles.
Calyx *sepals*	5	gamo- or monosepalous	free from ovary.
Corolla *petals*	5	gamo- or monopetalous	free.
Stamens	5	distinct	on corolla and opposite its segments.
Pistil *carpels*	5	united together	free from calyx.
Seeds	numerous, and on the axis.		

The blank schedule here filled out with the characters of the Order *Primulaceæ* consists of the upper line, denoting the value of the several columns, and the left-hand column, in which the organs are enumerated. The blanks may be constructed in any way the teacher may choose, provided the answers to be written in filling them up bear upon the number and relations, as to position and union, of the parts of the circles of the flower.

2. The second point of view from which a flower may be examined is that of Physiology. A flower is a mechanism for the production of seeds. All parts,

therefore, which are directly concerned in the production of seeds, must be taken into account.

Physiology.

Even the floral leaves or bracts, which are only indirectly tributary to the formation of seeds, must be regarded. The outer circles, the calyx and corolla, are generally termed unessential, because they are frequently merely protective, while the stamens and the carpels are the essential parts. The carpels contain the ovules, which are to become seeds; the stamens furnish the pollen, by the indirect action of which this change is to be brought about. Therefore, we might regard the ovules and the pollen as the only essential parts in the production of seeds. Each stamen consists of an anther, which is often supported upon a filament, or slender thread. "The anther is a sac filled with pollen, which most generally is like fine dust, but which is shown by the microscope to consist of minute grains of characteristic shape, size, and markings. The pistil is made up of one or more carpels, distinct or more or less completely blended together, and usually comprises three parts: (1) the ovary, holding the ovules; (2) the style, surmounting the ovary; and (3) the stigma, a point, or knob, or line of sticky surface at the side or summit of the style. The style may be wholly wanting.

Fertilization.

When the pollen acts upon the stigma, each grain may send down, after a time, a slender tube, which at last reaches an ovule. Here the contents of the tube act in some way upon the contents of a cell, or a group of cells, in the ovule, in which a new development begins, ending in the production of an embryo plant. The ripened ovule is a seed; the ripened ovary, with its contents, and often with some of its contiguous parts adherent, constitutes the fruit." It would seem, therefore, at first sight, as if flowers, in order to perfect seeds most readily, ought to be so constructed that the pollen can fall upon or reach the stigma without any difficulty. In some flowers, like the late and small flowers of our violets, and in a great many other cases, this is so: the pollen is placed by the anther directly upon the stigma, or the stamen is so placed that the pollen can very easily fall upon the stigma. But there are innumerable instances of just the opposite; and in these cases the transfer of the pollen must be made by the wind, by insects, or by some such agent. Some plants have the stamens only, while others of the same species have only the pistils. Willows are good examples of this kind of separation. Indian Corn is an example of a less complete separation. In this, the flowers with stamens form the plume above, and the pistils make up the ears with the silk (the styles and stigmas) below. The transfer of the pollen of Indian Corn is made by the wind, which can carry such dry dust to long distances. The pollen of some of our forest trees and shrubs is transferred by the same means, and it frequently falls by the way, collecting in large quantities on the leeward shores of lakes, where it resembles sulphur. There are many cases of separation of the stamens and pistil which are just as complete as Willow and Indian Corn, so far as the possibility of the pollen reaching the stigma without help is concerned; and yet the stamens and pistils are in the very same flower. For instance, in some orchids the pollen is packed away in a little pocket, from which it cannot fall to reach the stigma, but from which it is readily detached by the insect which comes to the flower in search of nectar. The insect unconsciously carries the package of pollen off to another flower, and here it is brought in contact with the stigma of that flower. These are among the most striking cases of complicated mechanism by which an end is reached, and they can best be understood by a careful study of Professor Gray's charming treatise, "How Plants Behave." Without engravings, which cannot be employed in this guide, their further description is undesirable. The object at present is merely to call attention to the interesting field opened before every observer of flowers. The transfer, in many cases, must be made by insect aid; but how can insects be made to work for something which does not concern them? There are many insects which are pollen-eaters. Such, coming to flowers for the pollen they get, might scatter more or less pollen around, and transfer some of it from one blossom to another; but there are more which are fond of the nectar of flowers. The nectar is for insects. It occurs in very diverse places in different blossoms, but it is almost always extensively and attractively advertised. Bright colors, with striking contrasts (the "nectar spot"), or with lines of contrasting color converging towards the cup of nectar (the "nectar guides"), show the insect visitors where their food can be found. A little attention will make clear the meaning of many of the colors which otherwise might be passed by without thought. There is hardly any phase of applied Morphology and Physiology in which pupils take more

Colors and fragrance.

interest than the investigation of color in flowers, and the insect visitors. Among the very striking features to be noticed in regard to colors of flowers is the remarkable one that outside parts, the floral leaves or bracts, often share or even monopolize the brilliancy and attractiveness.

Odors are in general indicative of the presence of nectar. The relations of color to fragrance, and both to the nectar which they advertise, will be found very attractive studies. Children can also be very intently absorbed by an unaided examination of the ways in which nectar is protected from injury by rain. The keen-sighted German, Sprengel, who at the close of the last century first called attention to the visits of insects to flowers in their search for food, observed especially the modes of nectar protection. One of these ways, described in his quaint language, is here spoken of. This case possesses much interest, for it appears to have been the one which earliest attracted him to this branch of investigation.

"When, in the summer of 1787, I carefully examined the flower of Wood Geranium (*Geranium sylvaticum*), I discovered that the lowest part of its petals was provided on the inner side and on both edges with fine, soft hairs. Convinced that the wise Author of nature has not made even a single hair without a definite design, I reflected upon the purpose which these hairs might serve. And it then occurred to me that if we suppose that the five drops of nectar, secreted from as many glands, are designed for the nourishment of certain insects, it might not be improbable that provision had been made to keep the nectar from injury by rain, and that these hairs are employed to attain this end. . .

Each drop of nectar rests on its gland immediately under the hairs which occur on the edges of two contiguous petals. Since the flower stands erect and is pretty large, it must catch rain-drops whenever it rains. But none of the drops which fall in can reach the nectar and mingle with it, for they are kept out by the hairs which cover it, just as the drops of perspiration which fall from the forehead are retained by the eyebrow and eye-lashes and kept from getting into the eye. And yet an insect is not hindered in the slightest from reaching the nectar. I next examined other flowers, and found that they had something in their structure different from the first, but which seemed to answer the same purpose. The further I prosecuted this investigation, the more plainly I saw that those flowers which possess nectar are so constructed that, although insects can easily get to it, the rain cannot injure it. Thereupon, I concluded that the nectar of those flowers is secreted chiefly for the sake of insects, and is protected against the rain so that they can enjoy it pure and uninjured." *

Sleep and waking of flowers and leaves.

It will also be found that children are greatly interested in the group of phenomena known as the sleep and waking of plants. Flowers of some species of Oxalis exhibit this very well under cultivation, and could be systematically observed, only the waking takes place long before school-hours. In some instances, the closing of flowers, which are to open again, appears to protect the pollen from night dampness. It may be here noted that pupils who can visit such gardens and wild fields as are accessible near a large city, might with a little pains ascertain what plants open and shut their blossoms at given hours,

* Das Entdeckte Geheimniss der Natur, 1793, p. 2.

and what flowers close at the approach of bad weather. Facts like these brought to school, and fresh from the lips of the young observers themselves, possess a wonderful attractiveness for teacher and all the pupils alike.

3. Flowers afford evidence of the degrees of kinship among the higher plants. The detection of the relationships belongs to Systematic Botany. Systematic Botanists rely upon the degree of resemblance as indicative of the degree of relationship; but the features which they take into consideration are not generally those which strike the eye at first. Therefore, a deeper search must be made; and the task is well adapted to a mature pupil, guided by a suitable hand-book of the principles of classification. But in our common schools this is impracticable. All that can be expected is to familiarize the older pupils with the systematic position of our common plants, as laid down in the Manuals of Botany; and this should only be done by the course marked out under the first part of this section, p. 45.

Systematic Botany.

Comparison of allied species is always useful, and some practice may be given in the elements of description. For the sake of acquiring the terms most readily, when the time has come for that, let the practice with fresh and dried specimens, and with such figures of plants as may be at hand, be thorough, but never tiresome. The mechanical execution of the chromo-lithographs of plants furnished the teachers in Boston appears to be excellent; and the selections are generally good, especially those of the "Poisonous Plants." Good figures of plants can be turned to good account for this purpose ;* but they must never be used to the exclusion of fresh specimens or well-preserved dried ones. Pupils should be early taught to dry and preserve plants. This task is very simple, and the collections are rapidly and easily made. Any common unglazed paper, like newspaper, will answer.

Preserving plants.

"In laying out the specimen for the press, use plenty of paper, so that their moisture may be quickly absorbed, and the danger of mould avoided. The specimens should be laid between the sheets of drying paper in as natural a position as may be, taking care not to crumple the leaves or flowers. If the specimens be too long for the paper, they may be carefully folded or cut in two. Delicate flowers should be carefully folded in paper when gathered, and kept flat. Do not arrange all the specimens just in the middle of the paper, but dispose them in such a way that, were a pile of them in their papers two feet high, they would not topple over: this will equalize the pressure. Several dry sheets ought to be laid between each layer of fresh specimens, the quantity of paper depending upon the thickness and succulence of the plants to be pressed. Pasteboards, or, better still, ventilators — made the size of the paper, of narrow strips of very thin pine wood (1-16 inch) at short distances apart, nailed together in two layers at right angles to each other — may be introduced at intervals between the layers of paper until the pile be ready for the press, which may consist simply of two stout boards, made so that they cannot bend or warp.

* A work by Professor T. Meehan, "Native Flowers and Ferns," contains many excellent plates, exhibiting the foliage and the general habit of the plants.

"Between these boards the paper and specimens must be placed, and a weight of stones or metal, not less than 50 or 60 lbs., laid upon the top.

"The papers should be changed several times once a day, and then at longer intervals, until the specimens are quite dry, when they should be removed from the press. If fresh specimens be placed in the press, while others are in process of drying, they must be carefully separated by pasteboard or by a thick layer of paper.

"The length of time which specimens ought to remain in the press varies with their nature, whether dry or succulent, and with the kind and quantity of paper used." *

One of the most successful preparers of specimens of dried plants has frequently said to his friends that "specimens are made or spoiled in the first twenty-four hours;" that is, the papers should be frequently changed, or as often as they become damp, during the first day.

When dried specimens of flowers are carefully soaked in warm water, the parts become so softened that they may be readily dissected. It is just about as easy, though not quite so interesting, to study dried specimens thus soaked, as it is to study fresh ones. Even the hastily gathered specimens which one collects during a rapid journey, and thrusts for preservation between the pages of a book, can be soaked out, dissected, studied, and named at the first leisure.

* Professor Oliver's Elementary Botany, p. 288.

IX. FRUITS AND SEEDS.

Fruits.

The ripened fruit-leaves, with their contents, constitute the fruit. But, in maturing, it is often the case that some other parts grow ripe too, and, clinging to the fruit proper, are to be regarded as a part of it. For instance, a strawberry is mainly a pulpy receptacle upon which are dotted the true fruits which look so much like seeds. This is not the place to classify or enumerate fruits; but a few words respecting some of the more common kinds may not be amiss. When the carpel or carpels ripen into fruit, the latter may open at maturity, or it may remain closed. The opening sorts are *pods* of many kinds, *capsules*, and so on: the closed sorts are the *berry*, in which the whole ovary ripens into a pulpy mass with a thin or thick skin; the *stone-fruit*, with a hard bony or stony shell in which is the seed, — the shell usually covered with a fleshy or fibrous mass, as in the peach and the almond; the *nut*, which has an extremely tough integument; and *akenes*, or *achenia*, which are one-seeded and dry fruits, usually small. Owing to the singular but not very deep disguises which the pistil takes on during its ripening into fruit, it affords a most excellent object of study by young scholars. They can watch the changes in an apple-blossom, for instance, and detect the character of the modifications which occur after the petals have fallen and the fruit begins to form. The range of fruits at the command of the teacher in a city is pretty wide, and yields material which may be utilized, not merely for talks which will be interesting, but for solid study which must be profitable.

Within the fruit are the seeds. An exception, which may be mentioned in passing, is found in the Conifers, including the Pines, Spruces, and so on, which have seeds, but do not possess any closed pistils; and so, according to the definition, *cones* are hardly to be called fruits. The seeds in fruits which remain closed are not furnished with any independent means for dispersal: here the dissemination is effected, if at all, by the fruit in some way. But the seeds of fruits which open at maturity are not infrequently furnished with wings, plumes, and hairs, upon which they can be carried in the air for considerable distances. Many of the one-seeded fruits which do not open when ripe have means for dissemination, such as wings, plumes, and hairs, like the seeds spoken of; and others have grappling-hooks, claws, teeth, and so on; while some of them are so constructed that they can be fastened securely in the ground when they have found a good place. A good case of this has been described by Hanstein.*

Seeds.

Dissemination.

"Each of the pods or valves of *Erodium* is pretty long and roundish near the base, where it is fastened by a point. At maturity, the outer side of each contracts by drying more strongly than the inner, and thereby causes an outward curvature and separation of the parts of the fruit. But, the tissue of the awn or prolongation of the pod being hygroscopic, it extends again by absorption of moisture from the air. On further drying, the awn by more complete contraction on one side rolls up to form a perfect screw, whilst only the upper extremity bends out into a sickle-like curvature. If the fruit is fastened perpendicularly on a support, the

* Botanische Zeitung, 1869, p. 530.

curved end moves like the hand of a watch, sometimes backwards, sometimes forwards, with every change in the amount of atmospheric moisture, and on this depends the well-known application of these fruits in the construction of simple hygroscopes. The very large fruits of *Erodium gruinum* are especially adapted for this study. When drying, the fruit forms a left-handed screw, so that with increase of moisture the tip turns like the hand of a watch; by diminution of moisture, it goes the other way. If such a fruit is put in a fresh and therefore extended state on soil which is not too moist, the tip of the beak will describe at first a broad lateral sickle-like curvature, while in its lower part twisting begins. Supported on the curved upper end, the fruit rises and by means of its point gains a position which is inclined to the ground. By increasing torsion, it therefore penetrates the soil, and straightway is fastened there, for it is wholly covered with little bristles which, being directed somewhat up, act like grappling-hooks. By further spiral movement, the fruit goes more deeply into the ground, since the end of the awn fixed in a slanting direction against the ground can neither penetrate it nor yield. While thus one turn follows another, the spiral nearest to the head of the fruit bores into the ground like a cork-screw, and pushes the true fruit before it and more deeply down."

The fruits of our cultivated Pelargonium exhibit nearly the same phenomena.

The good of wide dissemination is easily understood. It enables the embryo plant in the seed to have a better start in life than if it had to grow up under the shade of, and in rivalry with, the plant which produced it. In one very striking case, the seeds are furnished with hairs which are turned to great account in the arts.

Cotton consists of the plant-hairs found thickly packed upon the seeds of *Gossypium*. This plant-hair is the only one which has yet been sucessfully used in spinning.

Regarding the useful products from the vegetable kingdom other than those already mentioned, very little can now be said. In almost any of the treatises mentioned on page 10, teachers can find information respecting these: such as Rubber from the milky juice of many plants; Opium, the concrete milky juice of the unripe capsules of the Poppy; Cocoa from the seed of *Theobroma;* Tea from the leaves of a species of *Camellia;* Coffee, the seed of a subtropical tree; and so on.

Some useful products from plants.

X. MOVEMENTS, AND PARASITISM.

It remains now, in closing, to call attention to a few curious vegetable phenomena which always excite the interest of pupils: 1st, Movements. These may be (1) chiefly mechanical, as in the dried parts which change form and move, when water is applied. The "Resurrection Plant" of California, and the *Erodium*, p. 57, are good illustrations of this. (2) The spontaneous movements of twiners like Morning-glory and Hop-vine; (3) movements after touch or shock, as in the case of the Sensitive Plant. These are clearly described in "How Plants Behave." All the moving plants there spoken of can be cultivated with a little care in school-rooms.

Plant movements.

2d. The insectivorous plants, especially *Drosera*, can be grown with facility at any ordinary

Flesh-eating plants.

school-room window, and many of the phenomena described by Mr. Darwin in his "Insectivorous Plants" can be examined by the pupils. The tentacles of *Drosera* can be seen to bend over and down upon the prey which they sooner or later consume as food.

Lastly, attention should be called to the fact that many plants have no leaf-green (p. 29), and therefore have to depend upon other organisms for nutriment. They are generally white or whitish.

Parasitic plants.

"There are some parasites which obtain only a portion of their nourishment thus at second-hand: they possess more or less leaf-green, and are able to assimilate inorganic matter; but, at the same time, they attach themselves to the stems or roots of other plants and absorb elaborated juices from them. Such plants are called partial parasites. There are several species belonging to the Figwort family, in which this partial parasitism has been clearly demonstrated. As in the case of the Gerardias, the foliage is green, and the appearance of the plants does not suggest that they are obtaining any of their food in a surreptitious manner. A few of the roots become attached to the roots or underground stems of other plants, and draw from them elaborated nourishment." *

The parasites, just referred to, have flowers and produce true seeds; but by far the largest number of parasitic plants and of saprophytes belong to the lower groups which produce no seeds with embryo plants therein. These lower plants are termed Mushrooms, Moulds, and Rusts. It is in these latter groups that

* Sprague's Wild Flowers, p. 15.

the lower confines of the Vegetable Kingdom are reached. Such simple organisms, the yeast-cells, for instance, so far as the food is concerned, have so much in common with animals, that some naturalists have placed them in a middle kingdom between the vegetable and animal worlds, for they have some characters of both. At any rate, these lower plants, devoid of leaf-green, hide from view any sharp line of demarcation between plants and animals.